Complete Summary

GUIDELINE TITLE

Body plethysmography: 2001 revision and update.

BIBLIOGRAPHIC SOURCE(S)

Body plethysmography: 2001 revision and update. Respir Care 2001 May;46(5):506-13. [48 references]

COMPLETE SUMMARY CONTENT

SCOPE

DISEASE/CONDITION(S)

Pulmonary disease

GUIDELINE CATEGORY

Evaluation
Risk Assessment

CLINICAL SPECIALTY

Family Practice
Internal Medicine
Pediatrics
Pulmonary Medicine

INTENDED USERS

Respiratory Care Practitioners

GUIDELINE OBJECTIVE(S)

- To improve the consistency and appropriateness of respiratory care and serve as a guide for education and research
- To provide clinical practice guidelines on body plethysmography for determination of thoracic gas volume and airways resistance measurements

TARGET POPULATION

Pediatric, adult, and geriatric patients with pulmonary disease requiring body plethysmographic determination of thoracic gas volume (VTG), airways resistance (R_{aw}), or airways conductance (G_{aw}) under the following conditions:

- For diagnosis of restrictive lung disease
- For measurement of lung volumes to distinguish between restrictive and obstructive processes
- For evaluation of obstructive lung diseases, such as bullous emphysema and cystic fibrosis, which may produce artifactually low results if measured by helium dilution or N2 washout. With simultaneously determined volumes, an index of trapped gas (i.e., functional residual capacity $_{plethysmograph}$/ functional residual capacity $_{He\ dilution}$) can be established
- For measurement of lung volumes when multiple repeated trials are required, or when the subject is unable to perform multibreath tests
- For evaluation of resistance to airflow
- For determination of the response to bronchodilators as reflected by changes in airways resistance, specific airways conductance, and thoracic gas volume)
- For determination of bronchial hyperactivity in response to methacholine, histamine, or isocapnic hyperventilation as reflected by changes in thoracic gas volume, airways resistance, and specific airways conductance
- For following the course of disease and response to treatment

This Guideline does not apply to the neonatal population.

INTERVENTIONS AND PRACTICES CONSIDERED

Body plethysmography to measure thoracic gas volume (VTG) and airways resistance (R_{aw}) and calculate airways conductance (G_{aw}). Specific airways conductance (i.e., conductance/unit of lung volume) is routinely reported as sG_{aw}.

MAJOR OUTCOMES CONSIDERED

Accuracy and reproducibility of thoracic gas volume and airways resistance measurements

METHODOLOGY

METHODS USED TO COLLECT/SELECT EVIDENCE

Searches of Electronic Databases

DESCRIPTION OF METHODS USED TO COLLECT/SELECT THE EVIDENCE

Not stated

NUMBER OF SOURCE DOCUMENTS

Not stated

METHODS USED TO ASSESS THE QUALITY AND STRENGTH OF THE EVIDENCE

Not stated

RATING SCHEME FOR THE STRENGTH OF THE EVIDENCE

Not applicable

METHODS USED TO ANALYZE THE EVIDENCE

Systematic Review

DESCRIPTION OF THE METHODS USED TO ANALYZE THE EVIDENCE

Not applicable

METHODS USED TO FORMULATE THE RECOMMENDATIONS

Not stated

RATING SCHEME FOR THE STRENGTH OF THE RECOMMENDATIONS

Not applicable

COST ANALYSIS

A formal cost analysis was not performed and published cost analyses were not reviewed.

METHOD OF GUIDELINE VALIDATION

External Peer Review

DESCRIPTION OF METHOD OF GUIDELINE VALIDATION

Consultants to the Working Group may review the initial draft of the guideline. After completion by the Working group, the draft is reviewed by the entire Steering Committee and then by a Review Panel, persons engaged in all facets of the delivery of respiratory care who have volunteered to review drafts of the Guidelines before publication.

RECOMMENDATIONS

MAJOR RECOMMENDATIONS

Description/Definition:

During body plethysmography, the subject is enclosed in a chamber equipped to measure pressure, flow, or volume changes. The most common measurements made using the body plethysmograph are thoracic gas volume (VTG) and airways resistance (R_{aw}). Airways conductance (G_{aw}) is also commonly calculated as the reciprocal of airways resistance. Specific airways conductance (i.e., conductance/unit of lung volume) is routinely reported as sG_{aw}. Other tests that can be administered in the body plethysmograph include spirometry, bronchial challenge, diffusing capacity (D_{LCO}), single-breath nitrogen (N_2), multiple-breath N_2 washout, pulmonary compliance, and occlusion pressure. These will not be discussed as part of this guideline. Some have been previously addressed.

- Thoracic gas volume is expressed in liters (BTPS, or body temperature and pressure saturated) and is the volume of gas in the lung when the mouth shutter is closed. In plethysmographic studies, it is commonly used to represent the functional residual capacity (FRC)
- Airways resistance is reported in cm H_2O/L/s (i.e., cm H_2O x L^{-1} x s^{-1})
- Specific airways conductance is reported in L/s/cm H_2O (i.e., L x s^{-1} x cm H_2O^{-1}) and is the reciprocal of the airways resistance (1/airway resistance) divided by the lung volume at which the resistance measurement is made

Settings:

- Pulmonary function laboratories
- Cardiopulmonary laboratories
- Clinics and physician's offices

Limitations of Methodology/Validation of Results:

Limitations of the body plethysmograph in measurement of thoracic gas volume, airways resistance, and specific airways conductance include but are not limited to:

- Overestimation of thoracic gas volume in subjects with severe obstruction or induced bronchospasm unless a slow 'panting' speed (i.e., approximately 1 cycle/s) is maintained
- Erroneous measurement of thoracic gas volume, airways resistance, or specific airways conductance due to improper panting technique. Excessive pressure fluctuations or signal drift during panting may invalidate thoracic gas volume, airways resistance, or specific airways conductance
- Nonpanting measurements have been suggested for use in children or others who have difficulty mastering the panting maneuver. Nonpanting maneuvers in plethysmographs with built-in thermal leaks may invalidate thoracic gas volume or airways resistance, measurements
- Computer-determined slopes of either thoracic gas volume or airways resistance, tangents may be inaccurate. Many systems calculate the slopes

using a best-fit regression analysis. This technique may produce widely varying results if extraneous data points are included (due to improper panting or excessive signal drift). All slopes should be visually inspected and adjusted according to an established laboratory procedure
- Excessive abdominal gas or panting techniques that employ accessory muscles may increase the measured thoracic gas volume, due to compression effects
- Plethysmography is a complex test. Careful calibration of multiple transducers is required. Attention to frequency response, thermal stability, and leaks is necessary
- Choice and application of reference values affect interpretation. Reference values for thoracic gas volume using plethysmographically determined lung volumes are not widely available:
    - Make a tentative selection from whatever published reference values are available. The characteristics of the healthy reference population should match the study group with respect to age, body size, gender, and race. The equipment, techniques, and measurement conditions should be similar
    - Following selection of seemingly appropriate reference values, compare measurements obtained from a representative sample of healthy individuals (10-20 subjects, over an appropriate age range) to the predicted values obtained from the selected reference values. If an appreciable number of the sample fall outside of the normal range, more appropriate reference values should be sought. This procedure detects only relatively gross differences between sample and reference populations

Assessment of Need:

- See the section titled "Indications" in the original guideline document.
- Protocols may define the need for measurement of lung volumes and airway resistance measurements based on the results of previously performed tests (i.e., spirometry, diffusing capacity) and the clinical question to be answered

Assessment of Quality and Validation of Results:

The consensus of the Committee is that all diagnostic procedures should follow the quality model described in the NCCLS GP26-A A Quality System Model for Health Care (NCCLS, 940 West Valley Road, Ste. 1400, Wayne, PA 19087-1898; Web site: www.nccls.org). The document describes a laboratory path of workflow model that incorporates all the steps of the procedure. This process begins with patient assessment and the generation of a clinical indication for testing through the application of the test results to patient care. The quality system essentials defined for all health care services provide the framework for managing the path of workflow. A continuation of this model for respiratory care services is further described in NCCLS HS4-A A Quality System Model for Respiratory Care (NCCLS, 940 West Valley Road, Ste. 1400, Wayne, PA 19087-1898; Web site: www.nccls.org). In both quality models the patient is the central focus.

- General consideration include:
    - As part of any quality assurance program, indicators must be developed to monitor areas addressed in the path of workflow

        - Each laboratory should standardize procedures and demonstrate intertechnologist reliability. Test results can be considered valid only if they are derived according to and conform to established laboratory quality control, quality assurance, and monitoring protocols
        - Documentation of results, therapeutic intervention (or lack of) and/or clinical decisions based on the testing should be placed in the patient's medical record
        - The type of medications, dose, and time taken prior to testing and the results of the pretest assessment should be documented
        - Report of test results should contain a statement by the technician performing the test regarding test quality (including patient understanding of directions and effort expended) and, if appropriate, which recommendations were not met
        - Test results should be interpreted by a physician, taking into consideration the clinical question to be answered
        - Personnel who do not meet annual competency requirements or whose competency is deemed unacceptable as documented in an occurrence report should not be allowed to participate, until they have received remedial instruction and have been re-evaluated
        - There must be evidence of active review of quality control, proficiency testing, and physician alert, or 'panic' values, on a level commensurate with the number of tests performed
    - Calibration and quality control measures specific to equipment used in plethysmography include:
        - Calibration at recommended frequencies, at any time accuracy is suspect, and when the equipment is moved to a different location
        - On a daily basis, calibrate volume, mouth and box pressure
        - At least monthly, manually calibrate systems in addition to daily use of the autocalibration system
        - At least weekly, assess linearity of flow-sensing device
        - At least quarterly, perform airway resistance with a known resistor and calculate results
        - At least annually or at a frequency established by the laboratory on the basis of the tendency of the device to vary, check volume with isothermal bottle
        - At least monthly and at any time accuracy is suspect, perform tests on standard subjects (biologic controls, or bio-QC)
        - Test standard subjects more frequently initially to establish statistical variation for comparison
        - It may be advantageous to perform biologic controls at weekly or semi-monthly intervals
    - Test Quality Assessment: Results are valid if the equipment functions correctly and the subject is able to perform acceptable and reproducible maneuvers:
        - Thoracic gas volume maneuvers are acceptable when:
            - The displayed or recorded tracing indicates proper panting technique (the loop generated against a closed shutter should be closed or nearly so). The patient should support his/her cheeks with the hands to prevent pressure changes induced by the mouth. This should be done without supporting the elbows or elevating the shoulders
            - Recorded pressure changes should be within the calibrated pressure range of each transducer. The entire tracing should be

visible. Pressure changes that are too large or too small may yield erroneous results
        - Thermal equilibrium should be evident; tracings should not drift on the display or recording. (This typically takes 1-2 minutes.)
        - The panting frequency is approximately 1 Hz. Nonpanting maneuvers may be acceptable if the plethysmograph system is specifically designed to perform such maneuvers
- Airways resistance and specific airways conductance maneuvers may be considered acceptable if:
    - They meet the criteria given above (see "Test Quality Assessment," above)
    - The open-shutter panting maneuver shows a relatively closed loop, particularly in the range of +0.5 to -0.5 L/s
    - The panting frequency during serial measurements in a given patient is kept constant to aid in interpretation. Consensus of the group suggests a range of 90-150 cycles per minute (1.5-2.5 Hz). Frequency should be held constant for within-testing session comparisons (i.e., pre- and post-bronchodilator testing) and serial testing
- Test Results Reporting:
    - The reported thoracic gas volume:
        - Should be averaged from a minimum of 3-5 separate, acceptable panting maneuvers
        - Should be calculated using values that agree within 5% of the mean (widely varying values should be averaged, and reported as variable)
        - Should indicate whether the thoracic volume was at functional residual capacity or at some other level
        - Should be compared with other lung volume determinations (He dilution, N_2washout) if such are being performed
        - Should be corrected for patient weight for some systems
    - Lung volumes including the slow vital capacity (VC) maneuver and its subdivisions inspiratory capacity (IC) and expiratory reserve volume (ERV) should be performed during the same testing session. The expiratory reserve volume, inspiratory capacity, and vital capacity should be measured in conjunction with each thoracic gas volume trial before disconnecting from the measuring system. Add tracing to illustrate correct performance
        - The largest volume of vital capacity or forced vital capacity (FVC) obtained should be used for calculation of derived lung volumes (i.e., total lung capacity, or TLC, residual volume, or RV, and residual volume/total lung capacity%)
        - The mean values should be reported for inspiratory capacity and expiratory reserve volume from acceptable thoracic gas volume maneuvers
        - There are various methods to calculate total lung capacity, but by consensus the Committee recommends use of: total lung capacity = mean functional residual capacity + mean inspiratory capacity*

          *(Note: Mean inspiratory capacity should be close to the largest inspiratory capacity) residual volume = total lung capacity - largest vital capacity)

- The reported airways resistance and specific airways conductance:
    - Should be calculated from the ratio of closed and open shutter tangents for each maneuver. (Airway resistance and lung volume are interdependent in a nonlinear fashion)
    - Should be averaged from 3-5 separate, acceptable maneuvers as calculated in 9.4; reproducibility should be based on specific airways conductance and the suggested limit for variance is within 10% of the mean; (e.g., if the measured results are $\leq$0.17, accept ± 0.01 or if the measured results are $\geq$0.20, use ± 0.02)
    - Should have the open-shutter tangent (ventilation/perfusion$_{box}$) measured between flows of +0.5 and -0.5 L/s. For loops that display hysteresis, the inspiratory limbs may be used
    - Should have the specific airways conductance calculated using the thoracic gas volume at which the shutter was closed for each individual maneuver
- Report of test results should contain a statement by the technologist performing the test concerning test quality and, if appropriate, which recommendations were not met
- Reference equations: Each laboratory should select reference equations appropriate for the methods and the population tested. Guidance for defining and determining reference intervals is provided in American Thoracic Society (ATS) and NCCLS documents
- Test quality monitoring: Plethysmography results should be subject to ongoing review by a supervisor, with feedback to the technologist. The monitoring should include visual inspection of the thoracic gas volume and airway resistance loops and fitted lines. Quality assurance (QA) and/or quality improvement (QI) programs should be designed to monitor the technologist both initially and on an ongoing basis

Resources:

- Equipment:
    - Volume-measuring devices used in the plethysmograph (i.e., the pneumotachometer) should meet or exceed American Thoracic Society recommendations. A 3-L syringe should be available for calibration
    - Either pressure (constant volume) or flow-type plethysmographs may be used
    - Transducers in the plethysmograph should meet prescribed range specifications:
        - Mouth pressure: ±20 to 50 cm H_2O
        - Box pressure: ±2 cm H_2O (500-L box)
        - Flow: 0.2 to 1.5 L/s
    - Pressure and volumes signals should be phase aligned up to 10 Hz
    - A plenum or similar device that facilitates thermal equilibrium is recommended. Some plethysmographs utilize air conditioning to maintain thermal equilibrium
    - The plethysmograph cabinet should be easy for the subject to enter and exit. The door should preferably be operable from within the box. The cabinet should be equipped with an intercom and should provide adequate visibility for both the technologist and the subject
    - The plethysmograph system, if computerized, should allow for technologist adjustment of open- and closed-shutter tangents

- Calibration devices should include (in addition to a 3-L syringe) 30-50 mL sine-wave pump (variable speed, used primarily for calibration of pressure boxes), water manometer ±20 cm water (used for calibration of the mouth pressure transducer), and rotameter 0 to 1.5 L/s (used for calibration of the pneumotachometer)

Personnel: Plethysmography should be performed under the direction of a physician trained in pulmonary function testing. It may be performed by technologists who meet criteria for either Level I or Level II. Plethysmographic results can be compromised if the test is performed by inadequately trained personnel

- Level I: The technologist performing plethysmography should be a high school graduate or equivalent with a demonstrated ability to perform spirometry and lung volume determinations. Level I personnel should perform plethysmography only under the supervision of a Level II technologist or a physician
- Level II: Personnel supervising plethysmography should have formal education and training. This may be part of an accredited program in respiratory therapy or pulmonary function technology or 2 years of college work in biological sciences and mathematics. Level II personnel should also have 2 or more years experience performing spirometry, lung volumes, and diffusing capacity tests. Attainment of the credential of Certified Pulmonary Function Technologist (CPFT) or Registered Pulmonary Function Technologist (RPFT) is recommended

Patient Monitoring:

(See also "Assessment of Quality and Validation of Results," above)

- Evaluate the patient's breathing pattern to verify a stable functional residual capacity level
- Verify appropriate shutter-closure timing
- Gauge the level of understanding (of test instructions), effort, and cooperation by the subject

Frequency:

The frequency with which plethysmography is repeated should depend on the clinical question(s) to be answered.

Infection Control:

- The staff, supervisors, and physician-directors associated with the pulmonary laboratory should be conversant with the "Guideline for Isolation Precautions in Hospitals" by the Centers for Disease Control and Prevention and the Hospital Infection Control Practices Advisory Committee (HICPAC), and develop and implement policies and procedures for the laboratory that comply with its recommendations for "Standard Precautions" and "Transmission-Based Precautions"

- The laboratory's manager and its medical director should maintain communication and cooperation with the institution's infection control service and the personnel health service to help assure consistency and thoroughness in complying with the institution's policies related to immunizations, post-exposure prophylaxis, and job- and community-related illnesses and exposures
- Primary considerations include adequate handwashing, provision of prescribed ventilation with adequate air exchanges, careful handling and thorough cleaning and processing of equipment, and the exercise of particular care in scheduling and interfacing with the patient in whom a diagnosis has not been established. Considerations specific for plethysmography measurement include:
    - The use of filters is neither recommended nor discouraged. Filters may be appropriate for use in systems that use valves or manifolds on which deposition of expired aerosol nuclei is likely
    - If filters are used in gas-dilution procedures, their volume should be subtracted when functional residual capacity is calculated
    - If filters are used in the plethysmograph system, the resistance of the filters should be subtracted from the airways resistance calculation
    - Nondisposable mouthpieces and equipment parts that come into contact with mucous membranes, saliva, and expirate should be cleaned and sterilized or subjected to high-level disinfection between patients. Gloves should be worn when handling potentially contaminated equipment
    - Flow sensors, valves, and tubing not in direct contact with the patient should be routinely disinfected according to the hospital's infection control policy. Any equipment surface that displays visible condensation from expired gas should be disinfected or sterilized before it is reused
    - Water-sealed spirometers should be drained weekly and allowed to dry
    - Closed circuit spirometers, such as those used for He-dilution functional residual capacity determinations, should be flushed at least 5 times over their entire volume to facilitate clearance of droplet nuclei. Open circuit system need only have the portion of the circuit through which rebreathing occurs decontaminated between patients

Age-Specific Issues:

Test instructions should be provided and techniques described in a manner that takes into consideration the learning ability and communications skills of the patient being served.

- Neonatal: This guideline does not apply to the neonatal population
- Pediatric: These procedures are appropriate for children who can perform spirometry of acceptable quality and can adequately follow directions for plethysmographic testing
- Geriatric: These procedures are appropriate for members of the geriatric population who can perform spirometry of acceptable quality and adequately follow directions for plethysmographic testing

CLINICAL ALGORITHM(S)

None provided

EVIDENCE SUPPORTING THE RECOMMENDATIONS

TYPE OF EVIDENCE SUPPORTING THE RECOMMENDATIONS

Not specifically stated for each recommendation.

The guideline is developed from a thorough review of the literature, surveys of current practice, and the expertise of the members of the Working Group.

BENEFITS/HARMS OF IMPLEMENTING THE GUIDELINE RECOMMENDATIONS

POTENTIAL BENEFITS

- Effective utilization of body plethysmography
- Accurate measurement of thoracic gas volume (VTG); airways resistance (Raw); and airways conductance (sG_{aw})

POTENTIAL HARMS

- Thoracic gas volume and airways resistance measurements require the subject to pant against a closed shutter; improper panting technique may result in excessive intrathoracic pressures
- Prolonged confinement in the plethysmograph chamber could result in hypercapnia or hypoxia; however, because of the limited length of the test and the fact that the plethysmograph must be vented periodically, this is an uncommon occurrence
- Transmission of infection is possible via improperly cleaned equipment (i.e., mouthpieces) or as a consequence of the inadvertent spread of droplet nuclei or body fluids (patient-to-patient or patient-to-technologist)

CONTRAINDICATIONS

CONTRAINDICATIONS

Relative contraindications to body plethysmography are:

- Patients with mental confusion, muscular incoordination, body casts, or other conditions that prevent the subject from entering the plethysmograph cabinet or adequately performing the required maneuvers (i.e., panting against a closed shutter)
- Patients with claustrophobia that may be aggravated by entering the plethysmograph cabinet
- The presence of devices or other conditions, such as continuous intravenous infusions with pumps or other equipment that will not fit into the plethysmograph, that should not be discontinued, or that might interfere with pressure changes (e.g., chest tube, transtracheal O_2 catheter, or ruptured eardrum)
- Continuous oxygen therapy that should not be temporarily discontinued.

QUALIFYING STATEMENTS

QUALIFYING STATEMENTS

These procedures are appropriate for adults, as well as children and members of the geriatric population who can perform spirometry of acceptable quality and can adequately follow directions for plethysmographic testing.

IMPLEMENTATION OF THE GUIDELINE

DESCRIPTION OF IMPLEMENTATION STRATEGY

An implementation strategy was not provided.

INSTITUTE OF MEDICINE (IOM) NATIONAL HEALTHCARE QUALITY REPORT CATEGORIES

IOM CARE NEED

Getting Better
Living with Illness

IOM DOMAIN

Effectiveness
Safety

IDENTIFYING INFORMATION AND AVAILABILITY

BIBLIOGRAPHIC SOURCE(S)

Body plethysmography: 2001 revision and update. Respir Care 2001 May;46(5):506-13. [48 references]

ADAPTATION

Not applicable: The guideline was not adapted from another source.

DATE RELEASED

2001 May

GUIDELINE DEVELOPER(S)

American Association for Respiratory Care - Professional Association

SOURCE(S) OF FUNDING

American Association for Respiratory Care (AARC)

GUIDELINE COMMITTEE

Cardiopulmonary Diagnostics Guidelines Committee

COMPOSITION OF GROUP THAT AUTHORED THE GUIDELINE

Committee Members: Susan Blonshine BS, RPFT, RRT; Catherine Foss BS, RRT, RPFT; Carl Mottram BA, RRT, RPFT, Chair; Gregg Ruppel Med, RRT, RPFT; Jack Wanger MBA, RRT, RPFT

FINANCIAL DISCLOSURES/CONFLICTS OF INTEREST

Not stated

GUIDELINE STATUS

This is the current release of the guideline.

This guideline updates a previously issued version (Body plethysmography. Respir Care 1994 Dec;39[12]:1184-90).

GUIDELINE AVAILABILITY

Electronic copies: Available from the American Association for Respiratory Care (AARC) Web site.

Print copies: Available from AARC, CPG Desk, 11030 Ables Ln, Dallas, TX 75229-4593.

AVAILABILITY OF COMPANION DOCUMENTS

None available

PATIENT RESOURCES

None available

NGC STATUS

This summary was completed by ECRI on November 30, 1998. The information was verified by the guideline developer on December 15, 1998. This summary was updated by ECRI on August 24, 2001. The updated information was verified by the guideline developer as of October 17, 2001.

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